STRAIN-BASED DESIGN AND ASSESSMENT IN CRITICAL AREAS OF PIPELINE SYSTEMS WITH REALISTIC ANOMALIES

Contract Number: DTPH56-14-H-00003

Progress Review

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Project Review Meeting
September 09, 2014

Overview

- Project objectives
- Overall status
- Material procurement and specimen fabrication
- Small-scale tests
- Analyses and model development
- Summary and future work plan

Project Objectives

- Develop practical and ready-to-use guidelines and tools for strain-based design and assessment (SBDA) of pipeline segments containing:
  - Transition welds,
  - Corrosion defects, and
  - Dents.
- The limit states include:
  - Tensile strain – transition welds, corrosion defects
  - Compressive strain – transition welds, corrosion defects, and dents
  - Burst pressure under longitudinal strain – corrosion defects

Contractual Status

- Contract modification #2
  - Completed early September, 2014.
  - The project is now fully funded.
- Contract modification #3
  - Replace fittings with pups of various thickness to simulate transition joints
  - Add reference full-scale tests
  - Add associated pre-test analysis, small-scale testing, post-test data analysis, and model evaluation
  - Plan to submit to PHMSA by 09/15

Progress by Tasks

- Task 1 – confirmation of work scope and work plan
  - Completed
- Task 2 - development of test protocol and procedures
  - Completed
- Task 3 - pipe procurement and weld fabrication
  - Extensive activities and major focus so far
  - The completion time is delayed by 1-2 quarters
- Task 4 - small-scale tests
  - Test matrix finalized
  - Communicated with ASAP about the division of tests
  - The completion time is delayed by 2 quarters.
- Task 5-8 – analyses and model development
  - On schedule.
- Task 9-13 – full-scale and curved wide plate tests
  - The completion time is expected to be delayed by 1-2 quarters.

Progress by Tasks

Task No.	Task Description	Quarter from Project Start									
		1	2	3	4	5	6	7	8	9	10
1	Confirmation of Work Scope and Development of Detailed Work Plan	Original									
2	Development of Test Protocol and Procedures	Original	Original	Original							
3	Procurement and Fabrication of Test Welds	Original	Original	Original	Expected	Expected					
4	Small-scale material characterization tests		Original	Original	Expected	Expected					
5	Update and Development of Tensile Strain Models of Pipes without and with Fittings		Original	Original	Original	Original	Original	Original	Expected	Expected	
6	Update and Development of Compressive Strain Models of Pipes without and with Fittings		Original	Original	Original	Original	Original	Original	Expected	Expected	
7	Development of Integrity Assessment Models for Pipes with Corrosion Defects		Original	Original	Original	Original	Original	Original	Expected	Expected	
8	Development of Integrity Assessment Models for Pipes with Dents - buckling		Original	Original	Original	Original	Original	Original	Expected	Expected	
9	Full Scale Tests - Compressive Strain Capacity of Pipes with Fittings and Anomalies				Original	Original	Original	Expected	Expected		
10	Full Scale Tests - Pressure Containment of Pipes with Anomalies and High Longitudinal Strains				Original	Original	Original	Expected	Expected		
11	Full Scale Tests - Tolerance to Hoop Strain under High Longitudinal Strains				Original	Original	Original	Expected	Expected		
12	Full Scale Tests - Tensile Strain Capacity of Pipes in the Presence of Corrosion Defects				Original	Original	Original	Expected	Expected		
13	CWP Tests - Tensile Strain Capacity of Pipes with and without Fittings			Original	Original	Original	Original	Expected	Expected		
14	Development of Guidelines on SBDA							Original	Original	Expected	Expected
15	Project Management, Communication, and Reporting	Original	Original	Original	Original	Original	Original	Original	Original	Expected	Expected

Material Procurement - Pipes

- 36" OD, 16-mm and 19-mm WT, X70 pipes
  - For CWP tests
  - ASAP donating pipes
- 24" OD, 12.7-mm WT, X80 pipes
  - For full-scale post-buckling burst tests
  - Pipes with C-FER
- 12" OD, 6.4-mm WT, X60 pipes
  - For other full-scale tests
  - To be purchased from Evraz
  - Seven to ten 30-ft joints, two or three heats
- 12" OD, 7.9-9.5 mm WT, X60 pipes
  - For making transition welds of full-scale pipe tests
  - To be finalized and procured once other pipes are acquired

Specimen Fabrication – Making Girth Welds

- 36” X70 pipes, FCAW welds
  - To be provided by ASAP
  - Available by the end of September
- 36” X70 pipes, SMAW welds
  - Project to contract CRC to make the welds
    - Need to decide on welding process / parameters
    - Low hydrogen downhill vs. cellulosic welds (Exx10 electrodes)
  - In the process of obtaining a quote from CRC
    - May have cost implications
- 12" X60 transition welds
  - Fabrication plan – C-FER

Small-Scale Tests

- Testing matrix in a separate Excel file

Analyses and Model Development

- Testing support: (1) specimen design and (2) instrumentation plan
- Engineering analysis
  - The effect of joint-to-joint pipe strength variations on tensile strain design
- Related tasks

Task No.	Task Description	Quarter from Project Start							
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2	Development of Test Protocol and Procedures								
3	Procurement and Fabrication of Test Welds								
4	Small-scale material characterization tests								
5	Update and Development of Tensile Strain Models of Pipes without and with Fittings								
6	Update and Development of Compressive Strain Models of Pipes without and with Fittings								
7	Development of Integrity Assessment Models for Pipes with Corrosion Defects								
8	Development of Integrity Assessment Models for Pipes with Dents - buckling								
9	Full Scale Tests - Compressive Strain Capacity of Pipes with Fittings and Anomalies								
10	Full Scale Tests - Pressure Containment of Pipes with Anomalies and High Longitudinal Strains								
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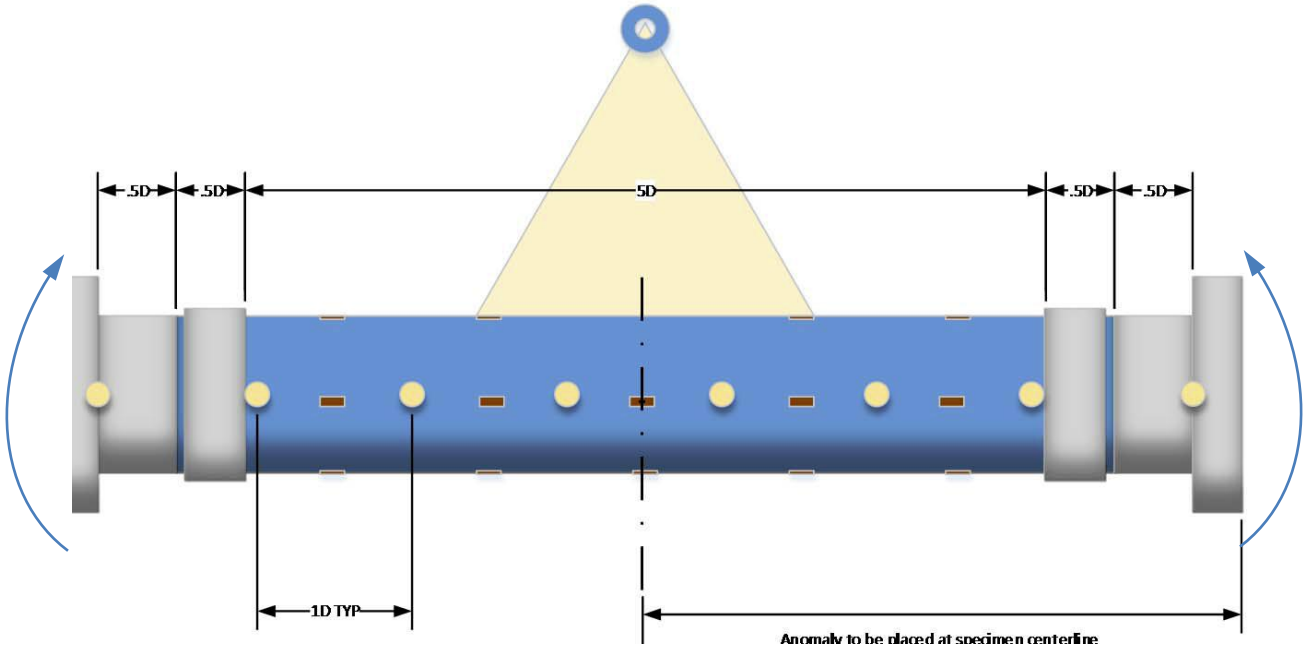
Analysis in Support of Large-Scale Tests

- Full-scale pipe tests
  - **Task 9 Bending tests for (12”) pipes with**
    - Transition welds,
    - **Corrosion defects, and**
    - Plain dents.
  - Task 10 Burst tests of (12”) pipes with corrosion defects under bending
  - **Task 11 Post-buckling burst tests of (24”) pipes**
  - Task 12 Tensile tests of (12”) pipes with corrosion defects
- Curved wide plate tests
  - Task 13 CWP tensile tests of (36”) pipes with
    - Girth welds (SMAW) of same wall thickness
    - Girth welds (FCAW) with thickness transition

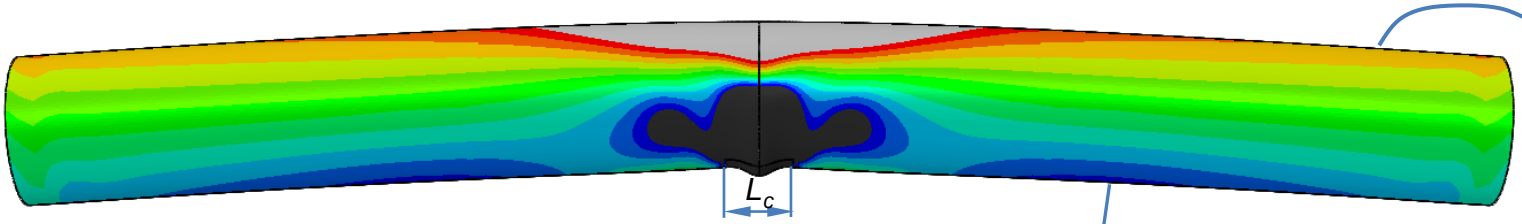
Task 9 Bend Test of Pipes with Anomalies

- Task 9b: full-scale bending tests of pipes with corrosion defects - compressive strain capacity
  - Loading sequence
    - I: Apply internal pressure
    - II: Apply axial compression to cancel the pressure-generated axial force
    - III: Apply bending till wrinkle forms

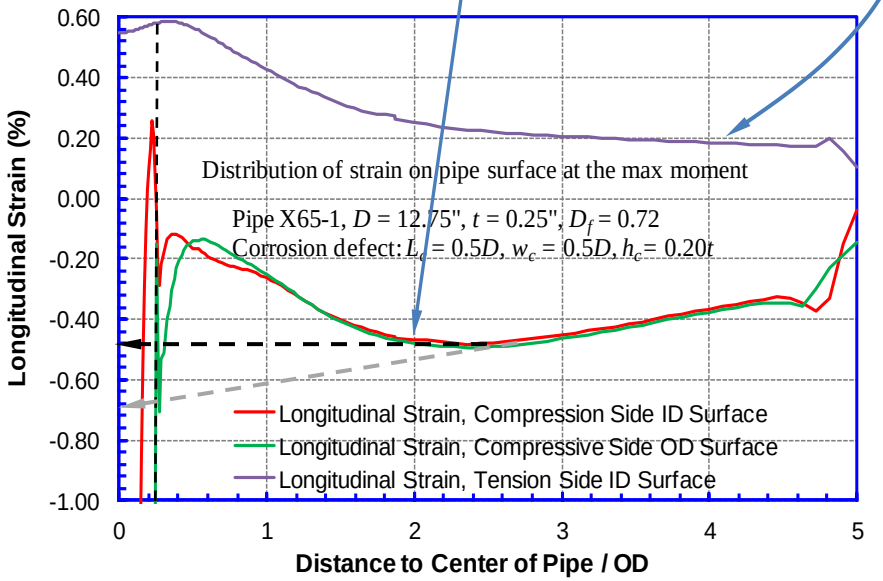


Numerical Simulation of Bend Test (Task 9)

- Objectives:
  - Provide assistance in specimen design and instrumentation plan
- Observations:
  - Wrinkle is formed inside the corrosion defect
  - High strain concentration is found at the wrinkle area

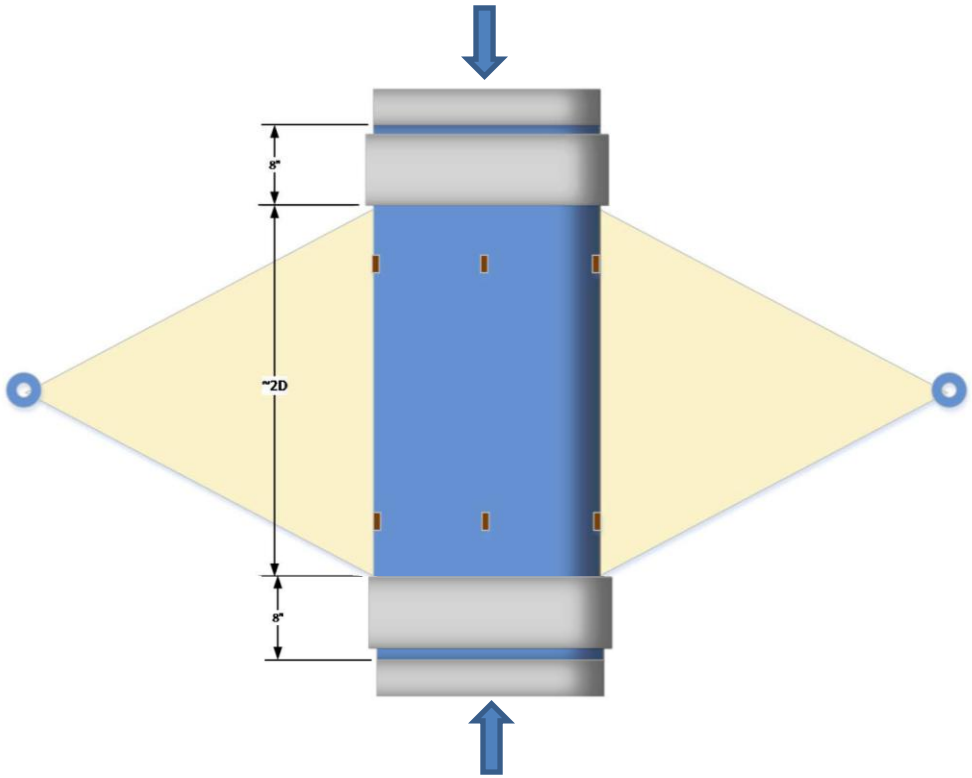


  - Strain in the area adjacent to the defect is very low
  - End effect ~ 0.5 OD
- Recommendations
  - Strain should be measured 2 OD away from the defect
  - If gauge length = 1 OD, the min specimen length should be 7 OD + defect length



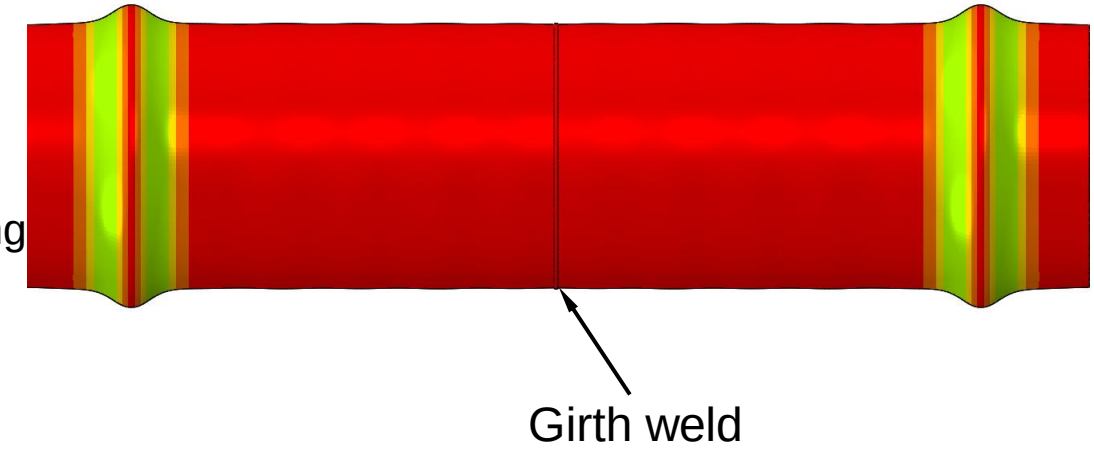
Task 11 Post-Buckling Burst Test

- Post-buckling burst tests – effect of buckle induced hoop strain
  - Loading sequence
    - I: Apply internal pressure
    - II: Apply compression force till wrinkle forms
    - III: Fixed axial displacement at pipe ends and increase pressure till burst



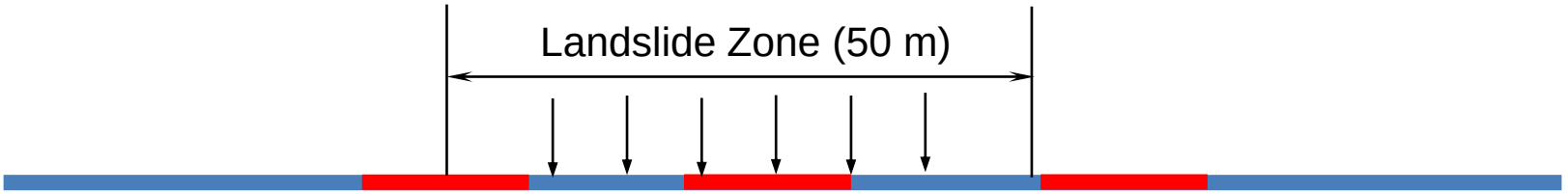
Numerical Simulation of Bucking Process (Task 11)

- Objectives
  - Provide assistance on specimen design and instrumentation plan
- Observations
  - For a plain pipe, it was found that the wrinkles tended to form at the ends of the pipe due to the discontinuity induced by the end conditions.
  - For a pipe containing a girth weld:
    - The wrinkle location depends on the competition between the discontinuities induced by the pipe ends and the girth weld.
    - The existence of the girth weld could increase the chances for making the wrinkles away from the pipe ends, but cannot guarantee it.
- Recommendations
  - Use pipes with girth welds
- Discussions
  - Other methods for controlling wrinkle locations



Effect of Pipe Strength Variations

- Objectives:
  - Understand the effect of pipe strength variation on tensile strain design
- Problem analyzed:
  - Landslide transverse to pipeline



Pipes of higher strength (strong pipe)

Pipes of lower strength (weak pipe)

Strong pipe: YS = 76 ksi, UTS = 86 ksi

Weak pipe 1: YS = 71 ksi, UTS = 78 kisi

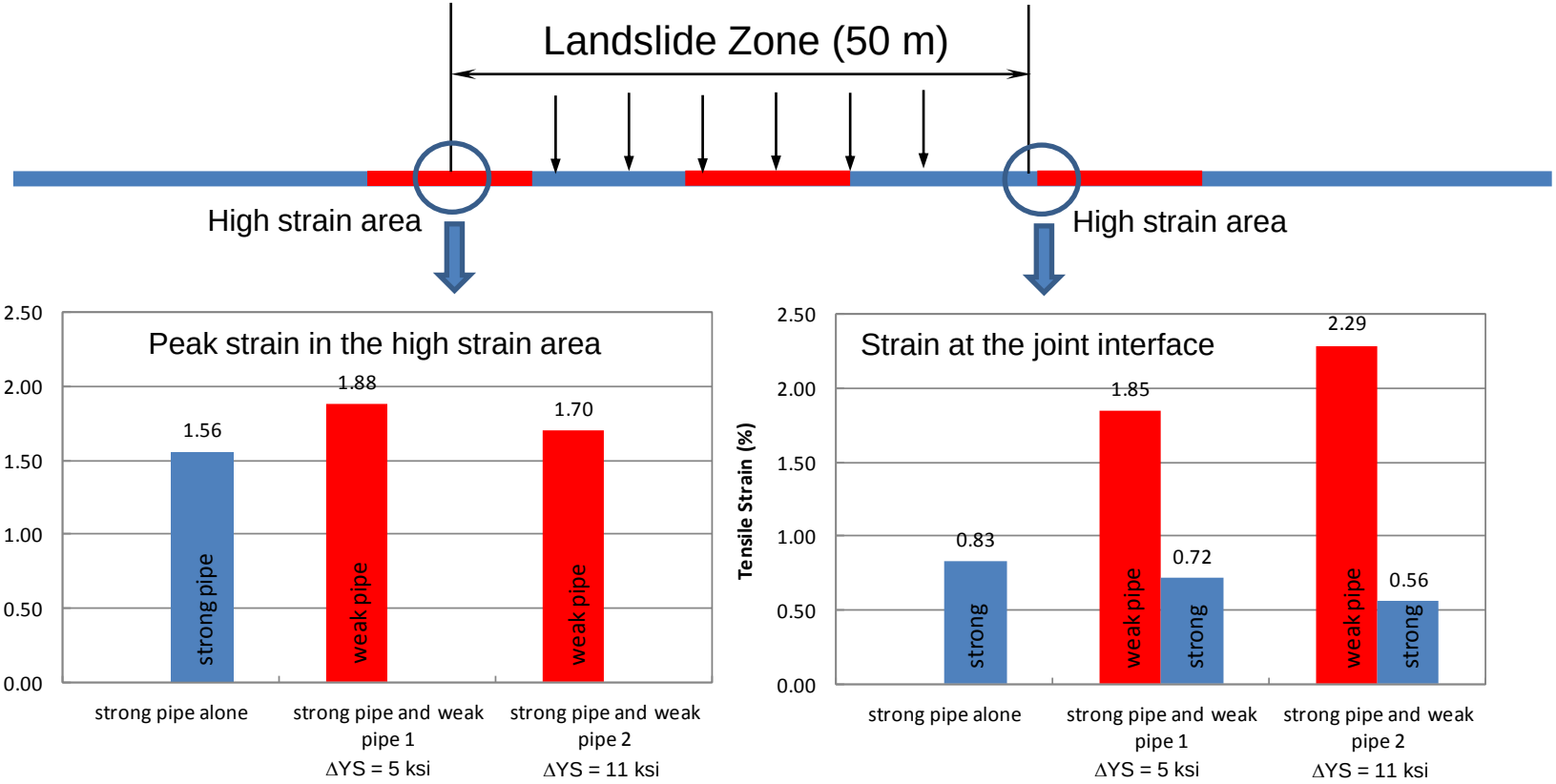
Weak pipe 2: YS = 65 ksi, UTS = 78 ksi

Strong – weak pipe 1: ΔYS = 5 ksi, ΔUTS = 8 ksi

Strong – weak pipe 2: ΔYS = 11 ksi, ΔUTS = 8 ksi

Effect of Pipe Strength Variations

- Observations:
  - The strain in the pipe string varies due to the pipe strength variation
  - The strain at a given point depends on the relative location of the strong/weak pipes and the ground movement.
  - The strain in the strong and weak pipes can be very different.



Status and Major Outcome

- Major efforts so far
  - Significant efforts on material procurement and weld fabrication
    - The overall picture is clear and the plan is in place.
    - The completion time is delayed.
  - Coordination with ASAP on small scale tests
  - Modeling effort in support of test specimen design and instrumental plan
  - Initial model development activities
- Contractual efforts
  - Contract Mod #2 was signed and the project is fully funded.
  - Contract Mod #3 is to be submitted by 9/15.
- Analysis to support full-scale tests
  - The specimen length for the bending tests of pipes with corrosion defects is increased with recommendations from FEA results.
  - For the post-buckling burst tests, a pipe section with girth weld is recommended.
- Model development
  - The joint-to-joint pipe strength variation was found to have large influence on the strain distribution along the pipe string.

Future Plan

- Work plan for the next 30 days
  - Submit contract Mod #3
  - Continue pipe procurement and weld fabrication
  - Continue analysis for the testing support and model development

Questions

- Thank you!